USER GUIDE
USB-6008/6009

This user guide describes how to use the National Instruments USB-6008/6009 data acquisition (DAQ) devices.

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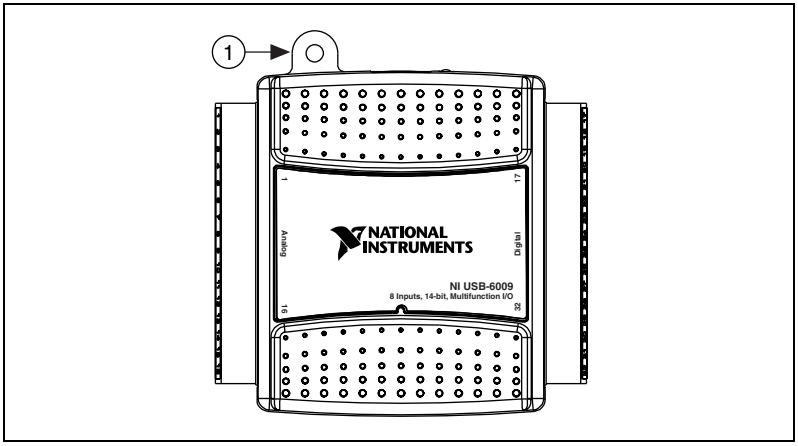
Introduction

The NI USB-6008/6009 provides connection to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels, and a 32-bit counter when using a full-speed USB interface.

Table 1-1. Differences Between the USB-6008 and USB-6009

Feature	USB-6008	USB-6009
AI Resolution	12 bits differential, 11 bits single-ended	14 bits differential, 13 bits single-ended
Maximum AI Sample Rate*	10 kS/s	48 kS/s
DIO Configuration	Open-drain	Open-drain or push-pull

* Might be system dependent



1 USB Cable Strain Relief

Figure 2. USB-6008/6009

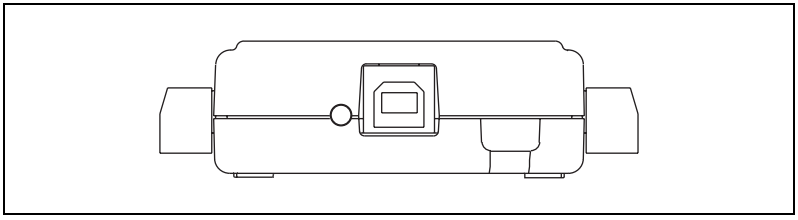


Figure 3. USB-6008/6009 Back View

Safety Guidelines

Caution Operate the hardware only as described in these operating instructions.

The following section contains important safety information that you must follow when installing and using the USB-6008/6009.

Do not operate the USB-6008/6009 in a manner not specified in this document. Misuse of the device can result in a hazard. You can compromise the safety protection built into the device if the device is damaged in any way. If the device is damaged, contact National Instruments for repair.

Do not substitute parts or modify the device except as described in this document. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions. You must have all covers and filler panels installed during operation of the device.

Do not operate the device in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the device in such an environment, it must be in a suitably rated enclosure.

If you need to clean the device, use a dry cloth. Make sure that the device is completely dry and free from contaminants before returning it to service.

Operate the device only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.

You must insulate signal connections for the maximum voltage for which the device is rated. Do not exceed the maximum ratings for the device. Do not install wiring while the device is live with electrical signals. Do not remove or add connector blocks when power is connected to the system. Avoid contact between your body and the connector block signal when hot swapping modules. Remove power from signal lines before connecting them to or disconnecting them from the device.

Operate the device at or below the Measurement Category I[1]. Measurement circuits are subjected to working voltages[2] and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Measurement categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of measurement categories:

- Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS[3] voltage. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

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[1] Measurement Category as defined in electrical safety standard IEC 61010-1. Measurement Category is also referred to as Installation Category.

[2] Working Voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

[3] MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.

- Measurement Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 V for U.S. or 230 V for Europe). Examples of Measurement Category II are measurements performed on household appliances, portable tools, and similar E Series devices.
- Measurement Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Measurement Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

Software

Software support for the USB-6008/6009 is provided by NI-DAQmx Base, which is a subset of the NI-DAQmx API.

The NI-DAQmx Base CD contains example programs that you can use to get started programming with the USB-6008/6009. Refer to the *NI-DAQmx Base 1.x Getting Started Guide* for more information.

Logging Application

NI-DAQmx Base includes ready-to-run datalogging software that allows you to take data measurements without programming first. The application is available at **Start»All Programs»National Instruments»NI-DAQmx Base»Datalogging Software**.

Self Test

NI-DAQmx Base includes an interactive control panel example that can be used to verify the operation of the USB-6008/6009. The application is located in **Start»All Programs»National Instruments»NI-DAQmx Base»Examples**.

The following block diagram shows key functional components of the USB-6008/6009.

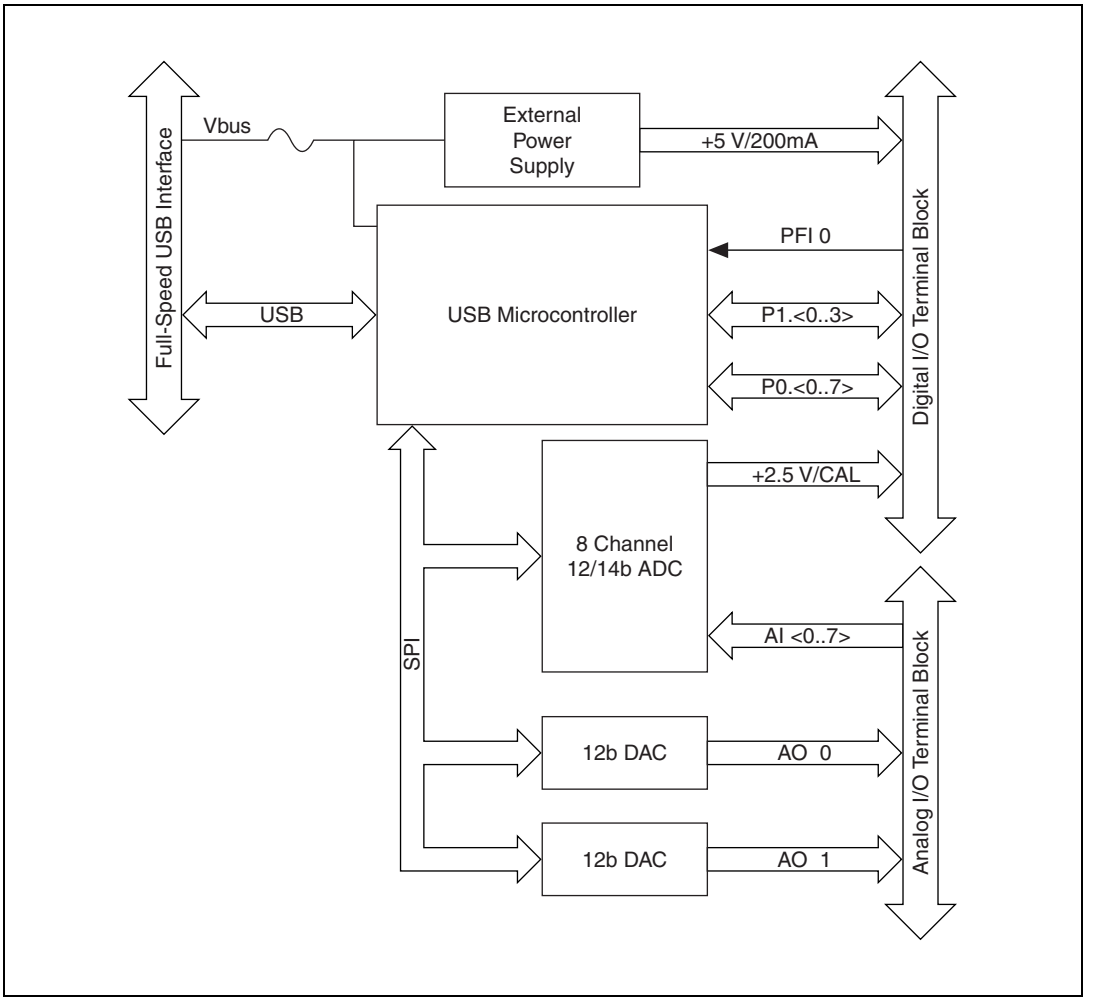


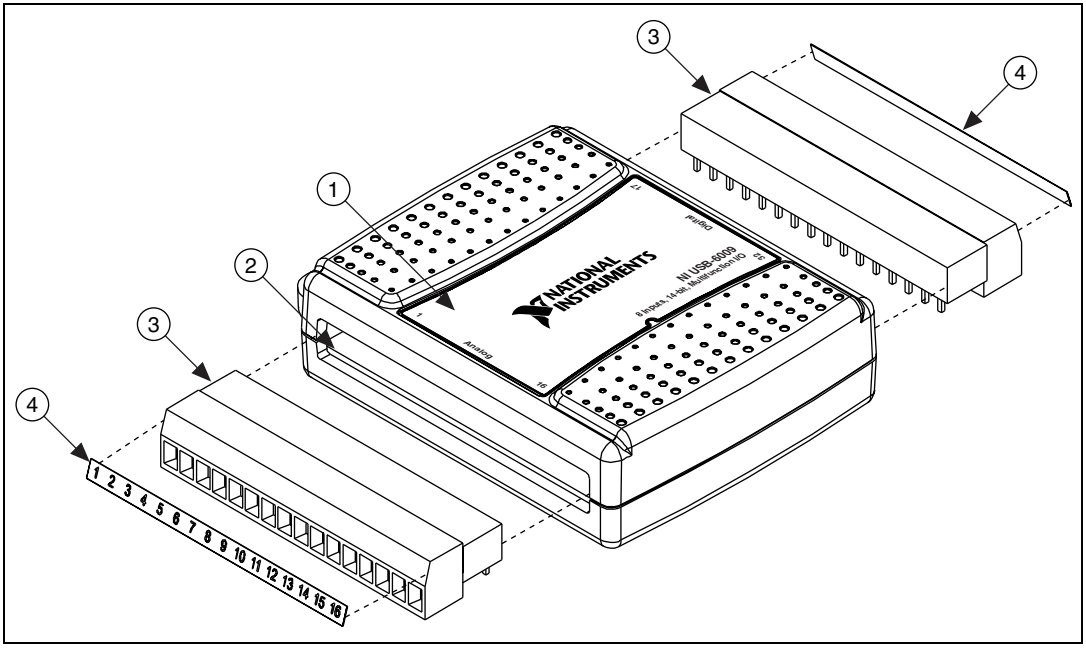
Figure 4. Device Block Diagram

Complete the following steps to set up the hardware:

1. Install combicon screw terminal blocks by inserting them into the combicon jacks.

Note The USB-6008/6009 kit ships with signal labels. You can apply the signal labels to the screw terminal blocks for easy signal identification.

2. Refer to Table 1 and Figure 5 for label orientation and affix the provided signal labels to the screw terminal blocks. Until the signal labels are applied, you can insert the screw terminal blocks into either of the combicon jacks. Refer to Figure 5 for more information about signal label orientation.



1	Overlay Label with Pin Orientation Guides	3	Screw Terminal Blocks
2	Combicon Jack	4	Signal Labels

Figure 5. Signal Label Application Diagram

Note Once you label the screw terminal blocks, you must only insert them into the matching combicon jack, as indicated by the overlay label on the USB-6008/6009 device.

3. Connect the wiring to the appropriate screw terminals.

I/O Connector

The USB-6008/6009 ships with one detachable screw terminal block for analog signals and one detachable screw terminal block for digital signals. These terminal blocks provide 16 connections that use 16 AWG to 28 AWG wire.

Table 1 lists the analog terminal assignments, and Table 2 lists the digital terminal assignments.

Table 1. Analog Terminal Assignments

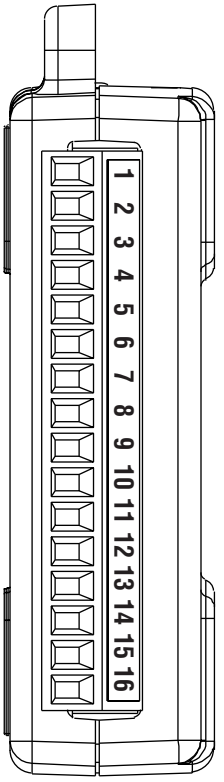
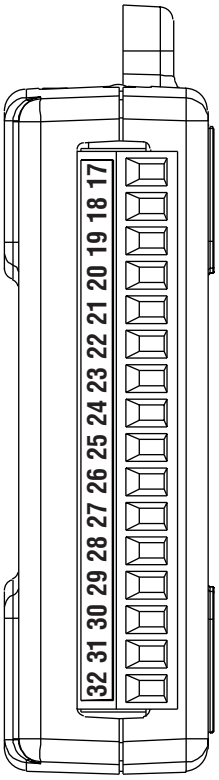
Module	Terminal	Signal, Single-Ended Mode	Signal, Differential Mode
	1	GND	GND
	2	AI 0	AI 0+
	3	AI 4	AI 0–
	4	GND	GND
	5	AI 1	AI 1+
	6	AI 5	AI 1–
	7	GND	GND
	8	AI 2	AI 2+
	9	AI 6	AI 2–
	10	GND	GND
	11	AI 3	AI 3+
	12	AI 7	AI 3–
	13	GND	GND
	14	AO 0	AO 0
	15	AO 1	AO 1
	16	GND	GND

Table 2. Digital Terminal Assignments

Module	Terminal	Signal
	17	P0.0
	18	P0.1
	19	P0.2
	20	P0.3
	21	P0.4
	22	P0.5
	23	P0 6
	24	P0.7
	25	P1.0
	26	P1.1
	27	P1.2
	28	P1.3
	29	PFI 0
	30	+2.5 V
	31	+5 V
	32	GND

Signal Descriptions

Table 3 describes the signals available on the I/O connectors.

Table 3. Signal Descriptions

Signal Name	Reference	Direction	Description
GND	—	—	**Ground**—The reference point for the single-ended AI measurements, bias current return point for differential mode measurements, AO voltages, digital signals at the I/O connector, +5 VDC supply, and the +2.5 VDC reference.
AI <0..7>	Varies	Input	**Analog Input Channels 0 to 7**—For single-ended measurements, each signal is an analog input voltage channel. For differential measurements, AI 0 and AI 4 are the positive and negative inputs of differential analog input channel 0. The following signal pairs also form differential input channels: <AI 1, AI 5>, <AI 2, AI 6>, and <AI 3, AI 7>.
AO 0	GND	Output	**Analog Channel 0 Output**—Supplies the voltage output of AO channel 0.
AO 1	GND	Output	**Analog Channel 1 Output**—Supplies the voltage output of AO channel 1.
P1.<0..3> P0.<0..7>	GND	Input or Output	**Digital I/O Signals**—You can individually configure each signal as an input or output.
+2.5 V	GND	Output	**+2.5 V External Reference**—Provides a reference for wrap-back testing.
+5 V	GND	Output	**+5 V Power Source**—Provides +5 V power up to 200 mA.
PFI 0	GND	Input	**PFI 0**—This pin is configurable as either a digital trigger or an event counter input.

Analog Input

You can connect analog input signals to the USB-6008/6009 through the I/O connector. Refer to Table 3 for more information about connecting analog input signals.

Analog Input Circuitry

Figure 6 illustrates the analog input circuitry of the USB-6008/6009.

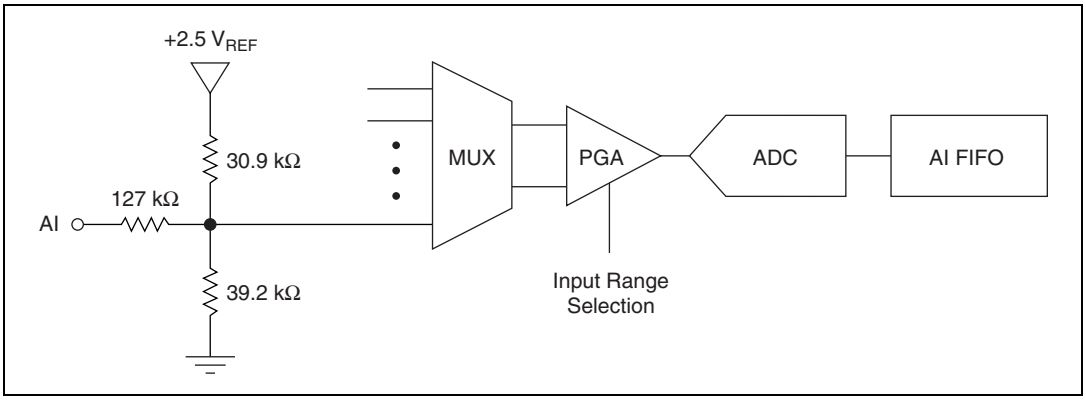


Figure 6. Analog Input Circuitry

MUX

The USB 6008/6009 has one analog-to-digital converter (ADC). The multiplexer (MUX) routes one AI channel at a time to the PGA.

PGA

The progammable-gain amplifier provides input gains of 1, 2, 4, 5, 8, 10, 16, or 20 when configured for differential measurements and gain of 1 when configured for single-ended measurements. The PGA gain is automatically calculated based on the voltage range selected in the measurement application.

A/D Converter

The analog-to-digital converter (ADC) digitizes the AI signal by converting the analog voltage into a digital code.

AI FIFO

The USB-6008/6009 can perform both single and multiple A/D conversions of a fixed or infinite number of samples. A first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure that no data is lost.

Analog Input Modes

You can configure the AI channels on the USB-6008/6009 to take single-ended or differential measurements. Refer to Table 3 for more information about I/O connections for single-ended or differential measurements.

Connecting Differential Voltage Signals

For differential signals, connect the positive lead of the signal to the AI+ terminal, and the negative lead to the AI– terminal.

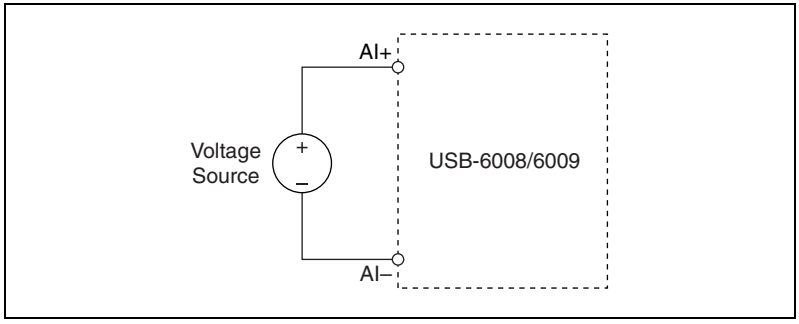


Figure 7. Connecting a Differential Voltage Signal

The differential input mode can measure ±20 V signals in the ±20 V range. However, the maximum voltage on any one pin is ±10 V with respect to GND. For example, if AI 1 is +10 V and AI 5 is –10 V, then the measurement returned from the device is +20 V.

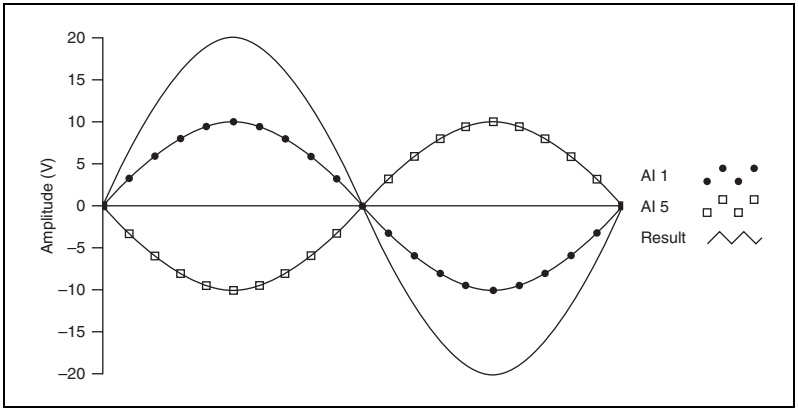


Figure 8. Example of a Differential 20 V Measurement

Connecting a signal greater than ±10 V on either pin results in a clipped output.

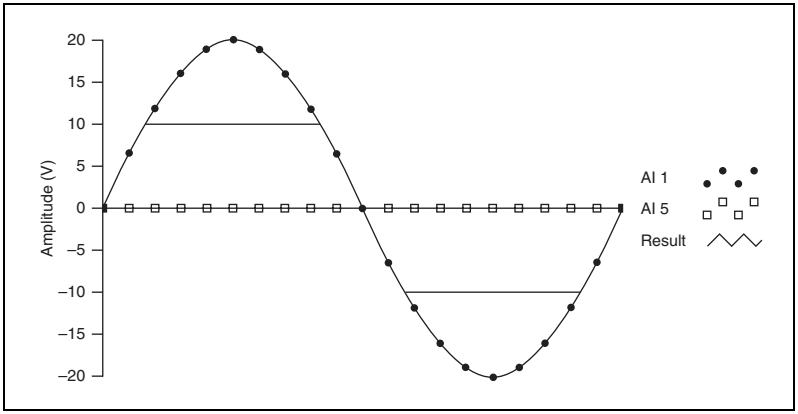


Figure 9. Exceeding +10 V on AI Returns Clipped Output

Connecting Reference Single-Ended Voltage Signals

To connect reference single-ended voltage signals (RSE) to the USB-6008/6009, connect the positive voltage signal to the desired AI terminal, and the ground signal to a GND terminal.

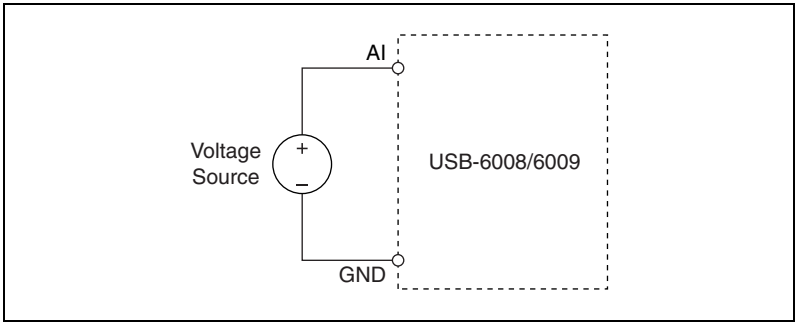


Figure 10. Connecting a Differential Voltage Signal

Digital Trigger

When an AI task is defined, you can configure PFI 0 as a digital trigger input. When the digital trigger is enabled, the AI task waits for a rising edge on PFI 0 before starting the acquisition. To use ai/Start Trigger with a digital source, specify PFI 0 as the source and select rising edge.

Analog Output

The USB-6008/6009 has two independent AO channels that can generate outputs from 0–5 V. All updates of AO lines are software-timed.

Analog Output Circuitry

Figure 11 illustrates the analog output circuitry for the USB-6008/6009.

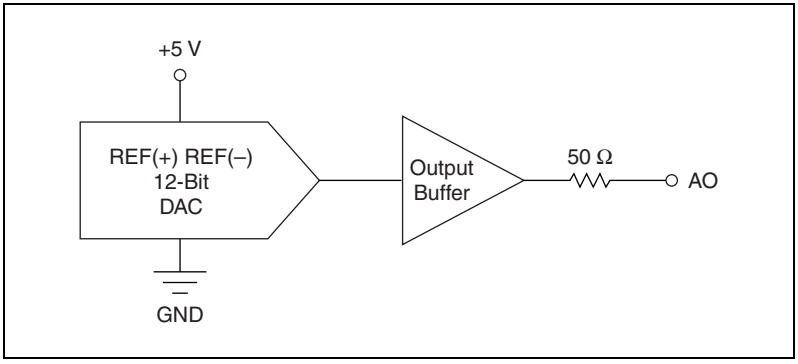


Figure 11. Analog Output Circuitry

DACs

Digital-to-analog converts (DACs) convert digital codes to analog voltages.

Connecting Analog Output Loads

To connect loads to the USB-6008/6009, connect the positive lead of the load to the AO terminal, and connect the ground of the load to a GND terminal.

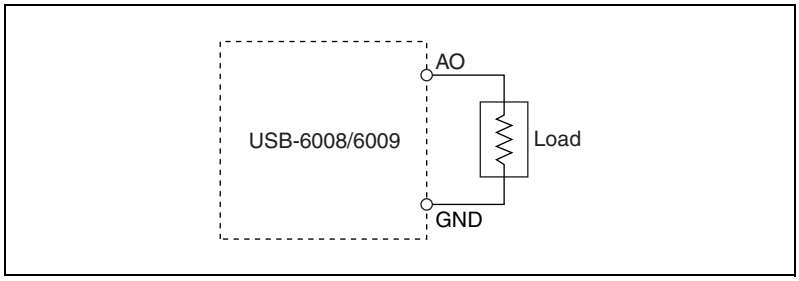


Figure 12. Connecting a Load

Minimizing Glitches on the Output Signal

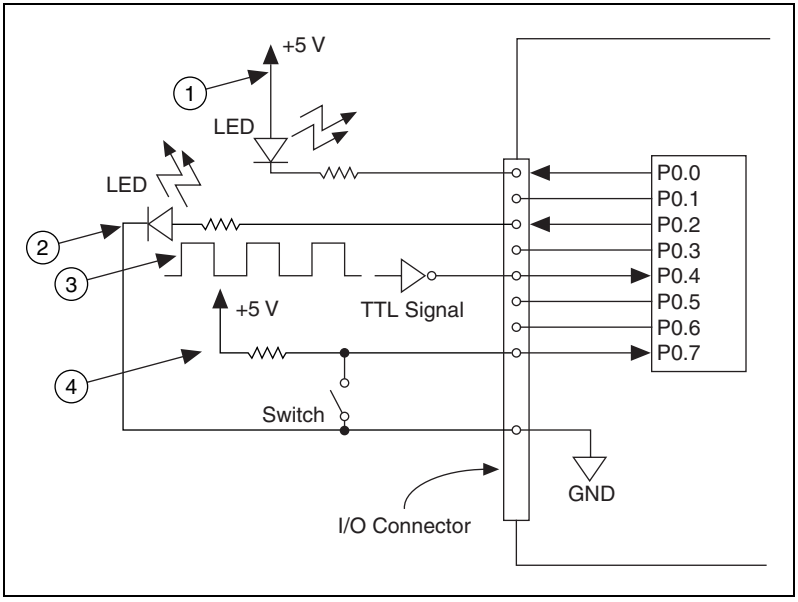
When you use a DAC to generate a waveform, you may observe glitches in the output signal. These glitches are normal; when a DAQ switches from one voltage to another, it produces glitches due to released charges. The largest glitches occur when the most significant bit of the DAC code changes. You can build a low-pass deglitching filter to remove some of these glitches, depending on the frequency and nature of the output signal. Refer to `ni.com/support` for more information about minimizing glitches.

Digital I/O

The USB-6008/6009 has 12 digital lines, P0.<0..7> and P1.<0..3>, which comprise the DIO port. GND is the ground-reference signal for the DIO port. You can individually program all lines as inputs or outputs.

Digital I/O Circuitry

Figure 13 shows P0.<0..7> connected to example signals configured as digital inputs and digital outputs. You can configure P1.<0..3> similarly.



1	P0.0 configured as an open-drain digital output driving a LED
2	P0.2 configured as a push-pull digital output driving a LED
3	P0.4 configured as a digital input receiving a TTL signal from a gated invertor
4	P0.7 configured as a digital input receiving a 0 V or 5 V signal from a switch

Figure 13. Example of Connecting a Load

Caution Exceeding the maximum input voltage ratings or maximum output ratings, which are listed in the specifications, can damage the DAQ device and the computer. National Instruments is not liable for any damage resulting from such signal connections.

Source/Sink Information

The default configuration of the USB-6008/6009 DIO ports is open-drain, allowing 5 V operation, with an onboard 4.7 kΩ pull-up resistor. An external, user-provided, pull-up resistor can be added to increase the source current drive up to a 8.5 mA limit per line as shown in Figure 14.

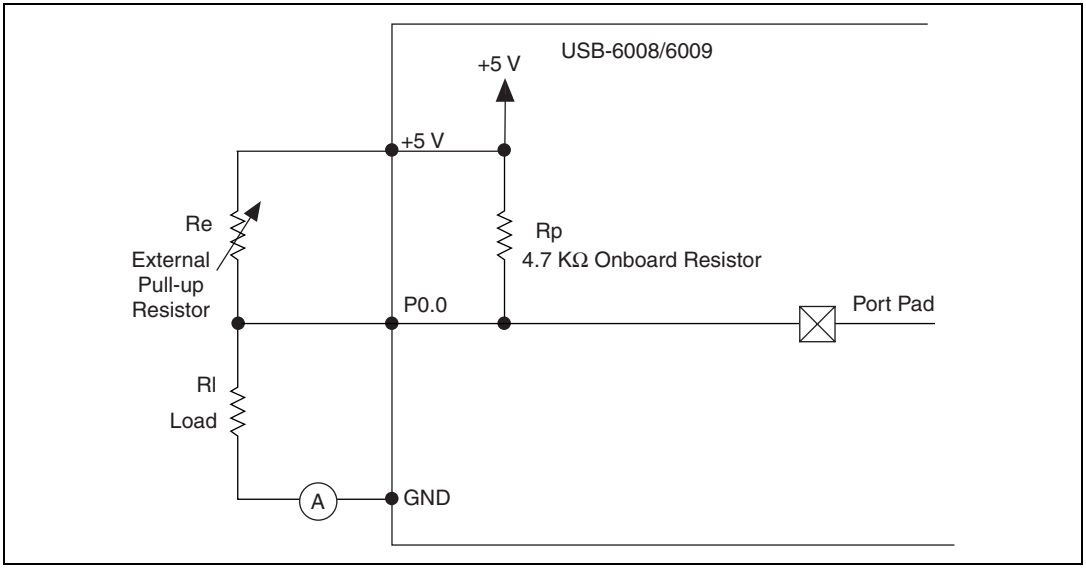


Figure 14. Example of Connecting External User-Provided Resistor

Complete the following steps to determine the value of the user-provided pull-up resistor:

1. Place an ammeter in series with the load.
2. Place a variable resistor between the digital output line and the +5 V.
3. Adjust the variable resistor until the ammeter current reads as the intended current. The intended current must be less than 8.5 mA.
4. Remove the ammeter and variable resistor from your circuit.
5. Measure the resistance of the variable resistor. The measured resistance is the ideal value of the pull-up resistor.
6. Select a static resistor value for your pull-up resistor that is greater than or equal to the ideal resistance.
7. Re-connect the load circuit and the pull-up resistor.

I/O Protection

To protect the USB-6008/6009 against overvoltage, undervoltage, and overcurrent conditions, as well as ESD events, you should avoid these fault conditions by using the following guidelines:

- If you configure a DIO line as an output, do not connect it to any external signal source, ground signal, or power supply.
- If you configure a DIO line as an output, understand the current requirements of the load connected to these signals. Do not exceed the specified current output limits of the DAQ device.

National Instruments has several signal conditioning solutions for digital applications requiring high current drive.

- If you configure a DIO line as an input, do not drive the line with voltages outside of its normal operating range. The DIO lines have a smaller operating range than the AI signals.
- Treat the DAQ device as you would treat any static sensitive device. Always properly ground yourself and the equipment when handling the DAQ device or connecting to it.

Power-On States

At system startup and reset, the hardware sets all DIO lines to high-impedance inputs. The DAQ device does not drive the signal high or low. Each line has a weak pull-up resistor connected to it.

Static DIO

Each of the USB-6008/6009 DIO lines can be used as a static DI or DO line. You can use static DIO lines to monitor or control digital signals. All samples of static DI lines and updates of DO lines are software-timed.

Event Counter

You can configure PFI 0 as a source for a gated invertor counter input edge count task. In this mode, falling-edge events are counted using a 32-bit counter. For more information about event timing requirements, refer to the *Specifications* section.

Reference and Power Sources

The USB-6008/6009 creates an external reference and supplies a power source.

+2.5 External References

The USB-6008/6009 creates a high-purity reference voltage supply for the ADC using a multi-state regulator, amplifier, and filter circuit. The resulting +2.5 V reference voltage can be used as a signal for self test. Refer to the *Self Test* section, for more information.

+5 V Power Source

The USB-6008/6009 supplies a 5 V, 200 mA output. This source can be used to power external components.

Note While the device is in USB suspend, the output is disabled.

Specifications

The following specifications are typical at 25 °C, unless otherwise noted.

Analog Input

Converter type ..... Successive approximation

Analog inputs ..... 8 single-ended/4 differential, software selectable

Input resolution

- USB-6008 ..... 12 bits differential, 11 bits single-ended
- USB-6009 ..... 14 bits differential, 13 bits single-ended

Max sampling rate[1]

- USB-6008 ..... 48 kS/s
- USB-6009 ..... 10 kS/s

AI FIFO ..... 512 bytes

Timing resolution ..... 41.67 ns (24 MHz timebase)

Timing accuracy ..... 100 ppm of actual sample rate

Input range

- Single-ended ..... ±10 V
- Differential ..... ±20 V, ±10 V, ±5 V, ±4 V, ±2.5 V, ±2 V, ±1.25 V, ±1 V

Working voltage ..... ±10 V

Input impedance ..... 144 kΩ

Overvoltage protection ..... ±35

[1] Might be system dependent

Trigger source.....Software or external digital trigger

System noise.....0.3 LSBrms (±10 V range)

Absolute accuracy at full scale, single ended

Range	Typical at 25 °C (mV)	Maximum over Temperature (mV)
±10	14.7	138

Absolute accuracy at full scale, differential[1]

Range	Typical at 25 °C (mV)	Maximum over Temperature (mV)
±20	14.7	138
±10	7.73	84.8
±5	4.28	58.4
±4	3.59	53.1
±2.5	2.56	45.1
±2	2.21	42.5
±1.25	1.70	38.9
±1	1.53	37.5

[1] Input voltages may not exceed the working voltage range.

Analog Output

Converter type .....Successive approximation

Analog outputs.....2

Output resolution .....12 bits

Maximum update rate.....150 Hz, software-timed

Output range .....0 to +5 V

Output impedance.....50 Ω

Output current drive.....5 mA

Power-on state .....0 V

Slew rate ..... 1 V/µs

Short circuit current ..... 50 mA

Absolute accuracy (no load) ..... 7 mV typical, 36.4 mV maximum at Full Scale

Digital I/O

Digital I/O

P0.<0..7> ..... 8 lines

PI.<0..3> ..... 4 lines

Direction control ..... Each channel individually programmable as input or output

Output driver type

USB-6008 ..... Open-drain

USB-6009 ..... Each channel individually programmable as push-pull or open-drain

Compatibility ..... TTL, LVTTL, CMOS

Absolute maximum voltage range ..... –0.5 to 5.8 V with respect to GND

Pull-up resistor ..... 4.7 kΩ to 5 V

Power-on state ..... Input (high impedance)

Digital logic levels

Level	Min	Max	Units
Input low voltage	–0.3	0.8	V
Input high voltage	2.0	5.8	V
Input leakage current	—	50	µA
Output low voltage (I = 8.5 mA)	—	0.8	V
Output high voltage			
Push-pull, I = –8.5mA	2.0	3.5	V
Open-drain, I = –0.6mA, nominal	2.0	5.0	V
Open-drain, I = –8.5mA, with external pull-up resistor	2.0	—	V

External Voltage

+5 V output (200 mA maximum) ..... +5 V typical, +4.85 V minimum

+2.5 V output (1 mA maximum) ..... +2.5 V typical

+2.5 V accuracy.....0.25% max

Reference temperature drift.....50 ppm/°C max

Counter

Number of counters 1

Resolution.....32 bits

Counter measurements .....Edge counting (falling-edge)

Pull-up resistor.....4.7 kΩ to 5 V

Maximum input frequency .....5 MHz

Minimum high pulse width.....100 ns

Minimum low pulse width.....100 ns

Input high voltage.....2.0 V

Input low voltage.....0.8 V

Bus Interface

USB specification .....USB 2.0 full-speed

USB bus speed.....12 Mb/s

Power Requirements

USB

- 4.10 to 5.25 VDC.....80 mA typical, 500 mA max
- USB suspend .....300 µA typical, 500 µA max

Physical Characteristics

If you need to clean the module, wipe it with a dry towel.

Dimensions

- Without connectors.....6.35 cm × 8.51 cm × 2.31 cm (2.50 in. × 3.35 in. × 0.91 in.)
- With connectors.....8.18 cm × 8.51 cm × 2.31 cm (3.22 in. × 3.35 in. × 0.91 in.)

I/O connectors ..... USB series B receptacle, (2) 16 position terminal block plug headers

Weight

With connectors ..... 84 g (3 oz)

Without connectors ..... 54 g (21 oz)

Screw-terminal wiring..... 16 to 28 AWG

Torque for screw terminals ..... 0.22 to 0.25 N · m (2.0 to 2.2 lb · in.)

Safety

Standards

The USB-6008/6009 is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1
- CAN/CSA-C22.2 No. 61010-1

Note For UL and other safety certifications, refer to the product label, or visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Voltages

Connect only voltages that are within these limits.

Channel-to-GND ..... ±30 V max, Measurement Category I

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as *MAINS* voltage. MAINS is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Caution Do not use this module for connection to signals or for measurements within Measurement Categories II, III, or IV.

Hazardous Locations

The USB-6008/6009 are not certified for use in hazardous locations.

Environmental

The USB-6008/6009 device is intended for indoor use only.

Operating temperature
(IEC 60068-2-1 and IEC 60068-2-2).....0 to 55 °C

Operating humidity
(IEC 60068-2-56) .....10 to 90% RH, noncondensing

Maximum altitude.....2,000 m (at 25°C ambient temperature)

Storage temperature
(IEC 60068-2-1 and IEC 60068-2-2).....–40 to 85 °C

Storage humidity
(IEC 60068-2-56) .....5 to 90% RH, noncondensing

Pollution Degree (IEC 60664).....2

Electromagnetic Compatibility

Emissions.....EN 55011 Class A at 10 m
FCC Part 15A above 1 GHz

Immunity .....Industrial levels per
EN 61326:1997 + A2:2001,
Table 1

EMC/EMI .....CE, C-Tick, and FCC Part 15
(Class A) Compliant

Note The USB-6008/6009 may experience temporary variations in analog input readings when exposed to radiated and conducted RF noise. The device returns to normal operation after RF exposure is removed.

CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety) 73/23/EEC

Electromagnetic Compatibility
Directive (EMC) 89/336/EEC

Note Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit `ni.com/certification`, search by model number or product line, and click the appropriate link in the Certification column.

Where to Go for Support

The National Instruments Web site is your complete resource for technical support. At ni.com/support you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

A Declaration of Conformity (DoC) is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electronic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting ni.com/certification. If your product supports calibration, you can obtain the calibration certificate for your product at ni.com/calibration.

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